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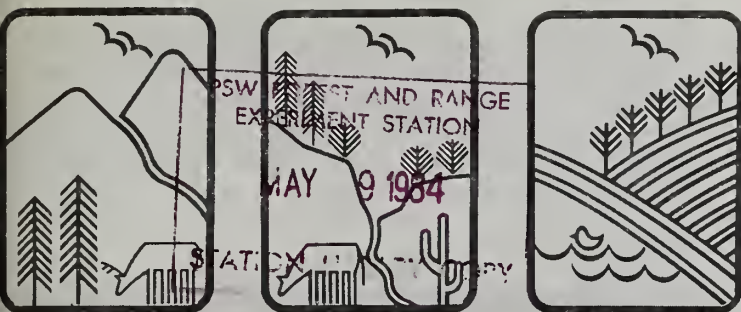
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Research Note RM-439

March 1984

USDA Forest Service

Rocky Mountain Forest and
Range Experiment Station

Survival and Height Growth of Norway Spruce in a Southcentral Nebraska Provenance Trial

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Among five Romanian provenances of Norway spruce (*Picea abies* (L.) Karst.) tested in southcentral Nebraska, a source from Pojoriata, survived best and grew tallest during an 8-year test period. Shading seedlings during field establishment significantly increased survival.

Keywords: *Picea abies*, provenance, seed source, artificial regeneration

Management Implications

Arborescent evergreen species native to the central Great Plains are limited to eastern redcedar (*Juniperus virginiana* L.), Rocky Mountain juniper (*J. scopulorum* Sarg.), ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engelm.), and limber pine (*P. flexilis* James) (Little 1971, 1979). Testing non-native coniferous species for adaptability to the Great Plains environment promises to increase the number and variety of species for planting in windbreaks, environmental improvement, and esthetic plantings throughout this region.

Based on this study, possible management alternatives include conversion of the trial into a seedling seed orchard; or establishment of a clonal seed orchard, with propagules from the best performing provenances, supplemented with selections of proven adaptability from area windbreaks and other plantings.

Introduction

Norway spruce (*Picea abies* (L.) Karst.), because of its temperature tolerance and attractive pendulous branching habit, is a candidate for use in Great Plains plantings. It is found in urban landscapes and occasionally in rural windbreak plantings throughout the central and northern Great Plains. However, the origin of these successfully growing Norway spruce trees is seldom known.

¹Research Forester, Rocky Mountain Forest and Range Experiment Station; headquarters is in Fort Collins, in cooperation with Colorado State University. Research reported here was conducted at the Station's Research Work Unit at Lincoln, Nebr., in cooperation with the University of Nebraska.

Material and Methods

Picea abies seeds from five Romanian provenances were obtained from the Institute of Forest Genetics at Placerville, Calif. in 1971 (table 1). The seeds were stored at -15.5°C until sown in Jiffy Pots² in April 1975. The seedlings were grown at a day/night temperature of $21^{\circ}/18^{\circ}\text{C}$, under normal daylength, for 5 months, in a glass greenhouse at Lincoln. In August 1975, the seedlings were transplanted into 0.95-liter plastic pots containing a 3:2:1 mix of soil, peat, and sand, and were randomly placed in an outdoor shadehouse. During the 1976 and 1977 growing seasons, the seedlings were watered, weeded, and fertilized monthly with 5 ml of Hyponex² per 3.8 liter of water.

In April 1978, 480 three-year-old seedlings were machine-planted at an open, level, and windy site in southcentral Nebraska, near Hastings ($40^{\circ}30'\text{N}$. latitude, $98^{\circ}18'\text{W}$. longitude). The elevation is 579 m; average annual precipitation is 610 mm; and the mean annual windspeed is 19 km per hour. The soil is a medium-to-heavy-textured silt loam.

The seedlings were spaced at 1.4-m intervals within rows 3.7 m apart. Provenances were replicated six times in a randomized complete block design. In each replication, a plot was one linear row of 16 seedlings of one provenance. A cedar shingle ($18 \times 41\text{ cm}$) was positioned on the south and on the west side of each odd-numbered seedling in each provenance plot. The objective was to determine the effect of shade on seedling

²The use of trade and company names is for the benefit of the reader, and does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Table 1.—Origins of *Picea abies* provenances tested in southcentral Nebraska

Provenance ID	Source
73-3	Cosna, Romania Lat. 47° 10' N Long. 25° 10' E Elev. 960 m
73-4	Frasin, Romania Lat. 47° 30' N Long. 25° 30' E Elev. 750 m
73-5	Candreni, Romania Lat. 47° 17' N Long. 25° 15' E Elev. 980 m
73-6	Moldovita, Romania Lat. 47° 35' N Long. 25° 34' E Elev. 855 m
73-7	Pojoriata, Romania Lat. 47° 24' N Long. 25° 25' E Elev. 1,000 m

survival and height growth. The shingles were removed in the fall of 1981, after the fourth growing season. The plantation was maintained by mowing between rows when needed, and by spraying a 51-cm band of the pre-emergence herbicide simazine 80W, at a rate of 4.5 kg per ha along both sides of each row, at the beginning of each growing season.

Chi-square analyses were employed to compare survival of provenances (Fleiss 1981), and analysis of variance was used to compare heights. Significance of test results was assessed at $\alpha = 0.05$.

Results

Survival

Seedling survival was 95% or more in all provenances at the end of the second growing season in the shadehouse (table 2). In the fall of 1982, after 5 years in the field, or 8 years from seed, mean plantation survival was 64% (table 3). Analyses of the proportions revealed that shaded trees survived significantly better (77%) than non-shaded trees (52%). The percent survival was

Table 2.—Second-year survival and heights of greenhouse/shadehouse grown *Picea abies* seedlings

Provenance ID	Survival 9/76	\bar{X} Height 9/76	
	(%)	(cm)	(in)
73-3	98.5	17.0	6.8
73-4	94.8	19.6	7.8
73-5	99.5	17.0	6.8
73-6	97.8	18.5	7.4
73-7	99.0	20.8	8.3
$\bar{X} =$	97.9	18.6	7.4

homogenous among shaded trees, but differed significantly among provenances of the non-shaded trees (table 3). Survival of shaded trees ranged from 90% in provenance 73-7 to 67% in provenance 73-4. Survival of non-shaded trees ranged from 73% in provenance 73-7 to 31% in provenance 73-5.

Height

In September 1976, heights of the 2-year-old greenhouse/shadehouse grown seedlings ranged from 21 cm in provenance 73-7 to 17 cm in provenances 73-3 and 73-5 (table 2).

Measurements in 1982, at age 8, showed ranges in mean tree heights of 0.79 m in provenance 73-7 to 0.56 m in provenance 73-5 (shaded); and 0.7 m in provenance 73-7 to 0.52 m in provenance 73-4 (non-shaded) (table 4). Tree height varied significantly with provenance among shaded trees, but not among the non-shaded trees (table 4). Tree heights were tallest in provenance 73-7, but not significantly taller than heights of trees in provenances 73-4 and 73-6 (table 4).

Table 3.—Survival of 8-year old *Picea abies* provenance trees in a southcentral Nebraska provenance trial

Provenance ID	Overall	Shaded ¹	Non-shaded ¹
	----- (%) -----		
73-5	52.1	72.9 a	31.2 a
73-3	63.5	79.2 a	47.9 a b
73-6	64.6	77.1 a	52.1 a b
73-4	60.4	66.7 a	54.2 a b
73-7	81.2	89.6 a	72.9 b
$\bar{X} =$	64.4	77.1	51.7

¹Numbers in the same column followed by the same letter suffix (a or b) do not differ significantly at the 5% level (Fleiss 1981).

Provenance and shading interacted significantly, indicating that the effect of shading differed from one provenance to another. Within provenance 73-4, the mean height for shaded trees was significantly greater than for non-shaded trees; however, this was the only provenance in which a difference was found related to shading.

Discussion and Conclusions

Shading and provenance origin significantly influenced the survival and height growth, respectively, of the five provenances tested. Except for the superior height of shaded over non-shaded trees in provenance 73-4, however, shading had no significant influence on height growth. The improved survival of all provenance trees under shading probably can be attributed to: (1) a reduction in solarization, a process in which photosynthesis is inhibited by high light intensities (Ronco 1970); and (2) less moisture loss through transpiration in the summer, and less dessication of leaves in the winter as a result of reduced wind velocities on the leeward side of the shingles.

Table 4.—Heights at eight years of shaded and non-shaded *Picea abies* trees in a southcentral Nebraska provenance trial

Provenance ID	1982 (all trees)					
	Shaded			Non-shaded		
	trees	\bar{X} height ¹		trees	\bar{X} height ¹	
	(no.)	(m)	(ft)	(no.)	(m)	(ft)
73-5	35	0.56 a	1.9	15	0.56 a	1.9
73-3	31	0.61 a b	2.0	23	0.64 a	2.1
73-6	37	0.70 a b c	2.3	25	0.67 a	2.2
73-4	32	0.73 b c	2.4	26	0.52 a	1.7
73-7	43	0.79 c	2.6	35	0.70 a	2.3
	185	\bar{X} = 0.68	2.27	124	\bar{X} = 0.62	2.08

¹Numbers followed by the same letter suffix (a, b, or c) do not differ significantly at the 5% level according to Tukey's Multiple Range Test.

Height growth during the 3-year greenhouse/shadehouse period and the 5-year field period was less than might be expected of the species elsewhere. Temperatures were very high and relative humidities very low during the summers the seedlings were in the outdoor shadehouse; and, probably more important, the environment of southcentral Nebraska is harsh, with strong persistent winds, low relative humidity, and limited precipitation. By comparison, mean heights of blue spruce (*Picea pungens* Engelm.) seedlings in a trial planted adjacent to the Norway spruce trial were only 50% of blue spruce seedlings of the same origins and age in an eastern Nebraska trial.³

Tests of *P. abies* in the northcentral region of the United States indicate that southern European provenances (Yugoslavian, Romanian, and others) are superior to far northern European provenances but somewhat inferior to eastern European provenances (Slabaugh and Rudolf 1957, King and Rudolf 1969, Van Deusen and Nienstaedt 1978). These tests, and those by Krutzsch (1974), Giertych (1976) and Prescher (1982), stressed the importance of seed source (provenance) in growing *P. abies*.

Romanian provenances also have performed well in the International Union of Forest Research Organizations 1938 and 1964/68 provenance tests in northern Europe and America, generally ranking at or above the plantation average in height growth (Krutzsch 1974, Giertych 1976).

The number of provenances in this trial is not large; and all originated from a small geographic area in the Carpathian Mountains of northeast Romania. There is no record available of the microsite characteristics (aspect, precipitation, etc.) of the provenance sites to explain performance differences in height among the five sources.

Among the five Romanian *P. abies* provenances, provenance 73-7 had the highest survival percentages and greatest height growth during the 8-year test period, but not significantly higher in survival or greater in height growth than provenances 73-4 and 73-6.

It is doubtful that seed could be recollected from the same stands in provenances 73-4, 73-6 or 73-7. There-

³Unpublished data on file, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Research Work Unit 2251, Lincoln, Nebr.

fore, assuming that the present developmental patterns continue, two future management alternatives seem feasible. First, convert the test site to a seedling seed orchard by eliminating provenances 73-3 and 73-5, and selectively thinning to the best four trees in each of the six replications of provenances 73-4, 73-6, and 73-7. This would leave 72 trees on the 0.4-ha test site—an acceptable seed orchard spacing of 7.7 × 7.7 m. Second, establish a clonal seed orchard with ramets from provenances 73-4, 73-6 and 73-7, supplemented with ramets from desirable phenotypes selected from Norway spruce trees of proven adaptability in area windbreaks or other plantings. The trees from windbreaks and other plantings have already demonstrated their genetic qualities of form and adaptability, and would increase the genetic diversity within the seed orchard. Ramets would be shaded during the establishment period.

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Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

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